On-line Monitoring in a Municipal Waste Water Treatment Plant in Northern Italy

The Realization and Management of a Toxicity and Organic load Monitoring System with Alarm at the inlet of a Municipal Wastewater Treatment Plant

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Summary

The following report addresses the structure, method of operation and management of a system for the detection of toxic loads present in the waste water pertaining to the waste water treatment plant for municipal waste serving a northern Italian city and 23 communities that surround it.

In the case of alarm, the system provides for an automated sequence which consents for the storage of more than 20,000 m3 of potentially polluted water.

Introduction

The wastewater treatment plant receives and treats the waste water produced in a northern Italian city and 23 communities on its outskirts.

Virtually 1,5 million inhabitants and 1800 industries totaling approximately 3 million inhabitants equivalent, discharge annually more than 230 million m3 of wastewater relative to an area of about 450 Kmq.

The presence of a significant amount of waste water coming from industries with a capacity which is at times very considerable, illustrates the problem of the prevention of eventual toxic discharges and/or prohibited in the biological phases of the plant.

For this reason, in addition to the process controls which are routinely made by means of laboratory analysis on representative samples collected from different sections of the plant, since the 1970's a inspection service for prevention has been operative and directly controls the quality of the industrial wastewater and verifies the efficiency of the treatment plant.

This type of prevention method has notably contributed to the regular functioning of the wastewater treatment plant. Nevertheless consistent (especially when near the periods of summer and winter closures of the producing entities) increases in industrial discharge, the effect of which could cause the reduction of the efficiency of the biologic reactors, can be verified.

To further increase the quality of protection, at the beginning of the 1990's an additional monitoring system was progressively structured based on the continuous on-line analysis of the *toxicity* of the influent to the plant.

The system is connected to an alarm mechanism which diverts the wastewater to a buffer tank having a capacity of more than 20,000 mc, in the event toxicity is detected during monitoring.

The object of this report is to describe the automated monitoring of toxicity with relative alarms as well as discussion of the principal aspects of the wastewater treatment plant and its management.

Description of the Monitoring System

1. General structure

The monitoring systems consist of two parallel on-line analyzers that continuously monitor the quality of the influent.

- A **toxicity monitor** operating by means of the respirometric principle, consists of a reactor that is continuously supplied with active sludge coming from the oxidation section of the plant. The possible influx of toxic substances can be correlated to a sudden drop in the level of consumption of the dissolved oxygen (D.O.).
- At the same time a **Total Organic Carbon (TOC)** instrument analyzes the organic load in the water, in order to establish if the reduced rate of oxygen consumption is physiological or the presence of an anomaly.

With the values recorded by the two instruments it is possible to verify an alarm or pre-alarm situation.

TOX	*TOC*	*Alarms*
> 2	**any value**	**no**
< 2	**< 25**	**no**
< 2	**> 25**	**pre-alarm**
< 2	**> 50**	**alarm**
< 1	**< 25**	**pre-alarm**
< 1	**> 25**	**alarm**

The pre-alarm and alarm signals emitted by the analyzers are processed by a computer installed in the control room. In the presence of the above conditions, wastewater can be diverted to three different sedimentation tanks that are normally kept empty for maintenance purposes.

The system operates as follows:

- **Pre-alarm** In this situation an audio and visual alarm will activate in the control room. Personnel is alerted of possible pre-alarm conditions of the influent water.
- **Alarm** When alarm conditions have been reached, personnel verifies that emergency procedures are carried out.

They consist of:

1.PLC control of which empty tank is available for the storage of the inlet water.

2.Activation of the procedures which will allow the influent water to be stocked in the buffer tanks depending on the resident time in the initial hydraulic part of the waste water plant.

3.Activation of the closure of each buffer tank after approximately an hour after they have been opened.

This will permit stocking of a total volume of more than 20.000 m3 of water in three tanks after alarm conditions are activated with a delay of:

- *22 minutes for the first buffer tank.*
- *28 minutes for the second buffer tank.*
- *36 minutes for the third buffer tank.*

2. The Instruments

The instruments used for monitoring are as follows:

A Toxicity Analyzer (TOX).

This is an instrument for the analysis of biological toxicity by means of the measurement of the O_2 consumption in a mixture consisting of wastewater, active sludge and dilution water in constant proportions.

Respiration takes place inside the bioreactor and the residual concentration of O_2 is measured by an oxygen probe.

The biomass is the same present in the aeration tanks and the wastewater (substrate) is sampled from the influent water. The dilution water is saturated with air and re-heated to 30°C and is used to supply the necessary oxygen for respiration of the biomass.

A computerized system calculates the difference of O_2 between entry and exit from the bioreactor, indicating this difference as the respiration rate. If the organic load of the wastewater is high, the consumption of O_2 is directly proportional to the toxicity present in the flow of the sample to analyze.

It is also possible to determine the consumption of O_2 due only to the endogenic respiration of the active sludge (in our case the recirculation sludge coming from the basin of secondary sedimentation), interrupting the flow of discharge water to analyze. In this way cumulative toxic effects are identified.

Considering that the instrument operates on wastewater, sample pretreatment is provided for with a self-cleaning filter with a 0.5 mm filter element at the inlet of the Toxicity Analyzer.

A Total Organic Carbon Analyzer T.O.C.

The TOC is an instrument for the measurement of total organic carbon with low temperature UV promoted persulfate oxidation.

The reagents utilized are phosphoric acid and sodium persulfate. For the quantitative determination of the CO_2 produced during the oxidation of the organics a nondispersive I.R. detector is used.

The sample of wastewater is filtered through a self-cleaning filter that uses compressed air.

As a carrier gas, the instruments use the compressed air locally available in the industrial network which is purified in order to remove ambient CO_2.

3. The Management and Maintenance of the System

The problems one may find with the management the toxicity analyzer are due to the nature of the influent to the municipal wastewater treatment plant.

The system is fed by a triturating pump positioned in the adduction canal of the wastewater in the purification plant after the grating station, to avoid extraction of solids of large dimensions.

The self cleaning filter at the inlet of the TOC analyzer has a 300 micron pore site.

For the TOX analyzer as well, a filter is installed to avoid blockage of the pumps and damage to the membrane of the probe used for measurement of the dissolved oxygen.

Manual cleaning of this filter must be done at least every fifteen days, and in particular cases weekly.

Particular attention must be given to the parts of the instruments subject to clogging - for example: turnouts, narrow sections.

The TOC in particular must be washed weekly with a hyperchlorite solution to avoid the formation of algae in the peristaltic pump tubings and the hydraulic system.

In addition to the cleaning operations, programmed as needed, a daily visual control of the functioning of the instruments is necessary (to check the pressure of liquids in the various circuits, the air pressure, for leaks, and reagent levels).

In order to effect all of the necessary controls and the ordinary maintenance of the system a specially trained team of laboratory personnel has been formed which check the instruments daily, in order to remain constantly up-to-date about instrument problems and maintenance to be done.

In the case of special technical needs service personnel (mechanical and electrical engineers) are available on request.

The system is calibrated on the basis of the alarm thresholds which were deduced from observations of the values of the consumption of oxygen of TOC normally verified in the treatment plant.

In certain periods of the year, a variation of the quality of the wastewater entering the plant can be expected.

In this case the threshold of alarm must be adapted to the new situation.

For example, in correspondence to the summer holiday period a significant drop is noted in organic material in the wastewater, which could potentially lead to a situation of instrumental alarm. In this case the alarms must be re-set and the minimum threshold values lowered, in order to avoid a false communication of toxicity.

Over all the system can be considered trustworthy in the protection of biological oxidation because it is able to reproduce the existing environment in a basin of active sludge.

It should also be pointed out that the system presents little sensibility to pollutants which selectively inhibit the nitrification process.

The nitrification process is more critical in respect to the oxidation of organics, as it is carried out by atrophied microorganisms, with the velocity of growth notably inferior in respect to that of the heterotrophs which effect the oxidation of the organic load.

The efficacy of the systems in comparison to anaerobic reactors is demonstrated with difficulty, due to the fact that the anaerobic biomass has different characteristics with respect to that used by the TOX.

4. Control System for Automated Systems and Alarms

Network of signals

The waste water treatment plants uses, for the management of the various treatment sections, a PLC network to acquire and distribute the different I/O signals interfaced through a fiber optic network, as well as a system of supervision, which includes the acquisition, management and storage of a great quantity of data.

The connections between the different stations and the field take place by means of traditional electrical connections.

One can therefore imagine that because of the need to interface several thousand digital points and several hundred analog points, an enormous quantity of cables is necessary for the realization of this system.

In consideration of the above, for the monitoring plant of the biological reactor a special system was chosen which, in addition to having a notable reduction in the number of cables connecting the different instruments in the field to the central station, permits the realization of a network of remote I/O for the PLC used for the management of the sequences necessary for storage in the case of toxic wave.

The system chosen bases itself on a “BUS system” and makes available, at any point in the transmission line, the digital and/or analog information, by simply setting the appropriate coded cards.

Since an internal telephone network was developed in the past, the same was used to connect the different stations previously seen, with the integration of only the terminal lines, making everything very rational in addition to economically advantageous.

The economic evaluation includes the electronic devices positioned in the different locations for the realization of the complete control on the level of an analogous traditional network.

Alarm management

We now briefly describe the management of the sequence of acquisition, sending of alarms and storage of potential toxic inlet waste water coming into the purification plant.

The on-line TOC and Toxicity analyzer, gives an analog signal (4 ¸20 mA) proportional to the measured range (0¸5 mg/l for the TOX and 0¸250 mg/l for the TOC)

The signals are transferred and linked in LOOP, to the central position, the management PLC, and the supervision system. The events are recorded.

The signals acquired by the PLC are continuously monitored on the basis of the pre-selected values for PRE-ALARM and ALARM.

The coincidental combination of the two different measured parameters may generate small peaks in the reading, which could be interpreted as a false pre-alarm or alarm condition.

As a result the measured values are continuously compared to previous results from the last 3 minutes in order to avoid false alarms.

If at the end of the 3 minute time, the measured values are confirmed, *pre-alarm* is subsequently confirmed.

At the *pre-alarm* reception stations *(WATCH STATION,*

SLUDGE LINE CONTROL ROOM, WATER LINE CONTROL ROOM), an acoustic and luminous signal is activated which can only be shut off by the service personnel.

At these stations messages of *INSTRUMENTAL ANOMALY* and *INTERRUPTION DATA TRANSMISSION LINE (BUS)* can also be received which, when signaled to maintenance, are the subject of the necessary verifications to return to a normal state.

After this first phase, the program, which is already in a state of alert, stands by for another 7 minutes (for a total of 10), after which the condition of *beginning to divert to a buffer tank* is activated which can no longer be re-set by the central position but only locally, acting on the basis of commands from the interception floodgates at the entrance to the buffer tanks,

To follow is some set data on the basis of trials effected to define execution time of the sequences:

- time to open the floodgates *6'15"*
- time required to fill basin *~ 1 h*
- time to close the floodgates *6'15"*
- volume stocked *~ 7.000 mc/h*
- propagation time of the toxic wave from the analysis point to the divider of the primary sedimentators *~ 25' with flow rate 10.000 m3/h*

Naturally the operating time differs by several additional minutes for the 2nd and 3rd units.

With the flowrates at the entrance of each unit lower than 7.000 m3/h the entire flow enters the basin while with a higher flowrate, the difference goes into the three primaries in use.

Example:

(9.100 m3/h - 7000) = 2.100 mc/h partitioned in the 3 basins at 700 mc/h each.

After another 12' -18' - 26' (22' - 28' - 36' respectively from the beginning of the event) the PLC sends a command for the opening of the floodgates of the appropriate sedimentators.

At this point, after 52' from the complete opening of the floodgates, the phase of complete closure begins during which stocking can be considered complete.

Therefore, from the beginning of the event to the completion of the stocking approximately 90' total have passed.

Completed this phase, the sequence is inhibited until the normal restoration of the same.

Naturally the state of the different components (about 90 points) which make up the protection system for the biological reactor is continuously monitored and checked in order to avoid incorrect action and/or anomalies which if are verified during the standby period could prejudice the stocking potential described.